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Summary of Hydroacoustic and Townetting Surveys Conducted at Red, Akalura, and Upper Station Lakes in Response to the 1989 *Exxon Valdez* Oil Spill 1990 - 1992

by
S. *G,* Honnold

Number 131

Alaska Department of Fish & Game
Division of Fisheries Rehabilitation,
Enhancement and Development

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Alaska Department of Fish and Game
Commercial Fisheries Management
and Development Division

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ABSTRACT

In 1989, as a result of the *M/V Exxon Valdez* Oil Spill (EVOS), commercial salmon fishing was closed in the Kodiak Management Area. Consequently, sockeye salmon (*Oncorhynchus nerka*) escapements into Red and Akalura lakes exceeded maximum desired escapement levels. In 1990 and 1991, hydroacoustic surveys were conducted on Red and Akalura lakes to estimate juvenile sockeye salmon populations and assess the potential damage as a result of this excess escapement. Upper Station Lake, which did not receive excess sockeye escapement in 1989, was also surveyed. Townetting was conducted in conjunction with these surveys to determine juvenile sockeye composition as well as to assess age structure and size. Juvenile sockeye population estimates were low for all lakes (101,000 and 632,000 for Red Lake; 209,350 and 44,380 for Akalura Lake; 1,171,200 and 391,000 for Upper Station Lake) and did not correspond with resulting smolt population estimates. Differential net avoidance during townetting as well as the distribution of fish in undetectable areas of the lakes during the hydroacoustic surveys most likely resulted in low juvenile sockeye population estimates. In 1992, hydroacoustic surveys were discontinued; however, townetting was, again, employed to provide age structure and size information. Size information suggests that age-1 Red Lake sockeye salmon fry from brood year (BY) 1989 reared under conditions that limited their growth, indicating the presence of interspecific competition. Juvenile sockeye fry in Akalura Lake were of good condition for BY 1989. Sockeye smolt sizes for BY 1988 through BY 1990 were similar, which indicates high escapement at Akalura Lake had no apparent effect. Upper Station Lake did not exhibit large changes in juvenile sockeye salmon size for BY 1988 through BY 1990.

INTRODUCTION

In 1989, as a result of the EVOS, commercial salmon fishing was closed in the Kodiak Management Area. Consequently, sockeye salmon escapements into Red and Akalura lakes exceeded maximum desired escapement levels. Sockeye escapement into Red Lake was 768,000, a 2.5-fold increase from the management goal of 200,000 to 300,000. Akalura Lake sockeye escapement was 116,000, well above the 40,000 to 60,000 goal (Barrett et al. 1992). Upper Station Lake sockeye escapement of 286,000, however, did not significantly exceed the management goal of 200,000 to 275,000.

Productivity in lakes can be adversely affected by adult sockeye salmon escapement levels, which result in the production of an over abundance of juvenile sockeye. Kyle et al. (1988) found that large sockeye escapements into Frazer Lake resulted in increased fry densities with a subsequent decrease in rearing fry growth due to overutilization, thus decreased size and abundance of the zooplankton community. Kyle et al. (1988) also noted that poor growth among fry can lower their overwinter survival and, consequently, limit smolt production. The large escapements into Frazer Lake resulted in decreased smolt production; thus, few adult returns. The level of adult returns limited fishing opportunity and did not meet escapement objectives (Barrett 1989). The excessive escapements into Red and Akalura lakes in 1989 may produce similar returns.

Estimating the number and distribution of juvenile sockeye salmon rearing in nursery lakes and determining their age and condition is important for assessment of rearing habitat productivity. Exceeding the rearing capacity of a nursery lake may result in negative impacts that are exhibited at each trophic level and may persist for an extended period.

Echosounders have been used to study fish distribution and relative abundance since the mid-1930s (Thorne 1983). Recent improvements in acoustic equipment have resulted in the ability

to determine total fish population estimates and spatial distribution in a variety of settings, including lakes. Sockeye salmon population estimates can be determined by applying ground-truthing techniques, such as townetting. Townet catches are evaluated for species composition, and these proportions are applied to total population numbers to estimate the juvenile sockeye salmon population.

Hydroacoustic and townetting surveys were initiated in 1990 to provide estimates of sockeye fry populations, as well as age and size information at Red, Akalura, and Upper Station lakes. Upper Station Lake was considered the control site. The purpose of this report is to document and summarize total juvenile fish population estimates, spatial distributions, juvenile sockeye salmon population estimates, and age and size information determined from acoustic and townet surveys. In addition, age, weight, and condition information are presented from townet surveys conducted in 1992 at Red and Upper Station lakes.

Description of Study Area

Red Lake (57°15'N; 154°20'W) is located 128 km southwest of the City of Kodiak (Figure 1). It is 6.4 km long, up to 1.4 km wide, and has a total surface area of 8.4 million m^2. The mean depth of Red Lake is 24.7 m and the lake is classified as oligotrophic. The annual precipitation in this area is 152.4 cm, watershed drainage area is 43.8 km^2, and lake water residence time is 4.0 years.

Akalura Lake (57°11'N; 154°15'W) is located 1.6 km south of Red Lake. It is composed of a north-south arm, 3.2 km long, 1.2 km wide, and an east-west arm, 4.0 km long and 0.8 km wide. Lake surface area is 4.9 million m^2 and mean depth is 9.9 m. Akalura Lake is oligotrophic. The watershed drainage area is 31.6 km^2, and lake water residence time is 1.3 years.

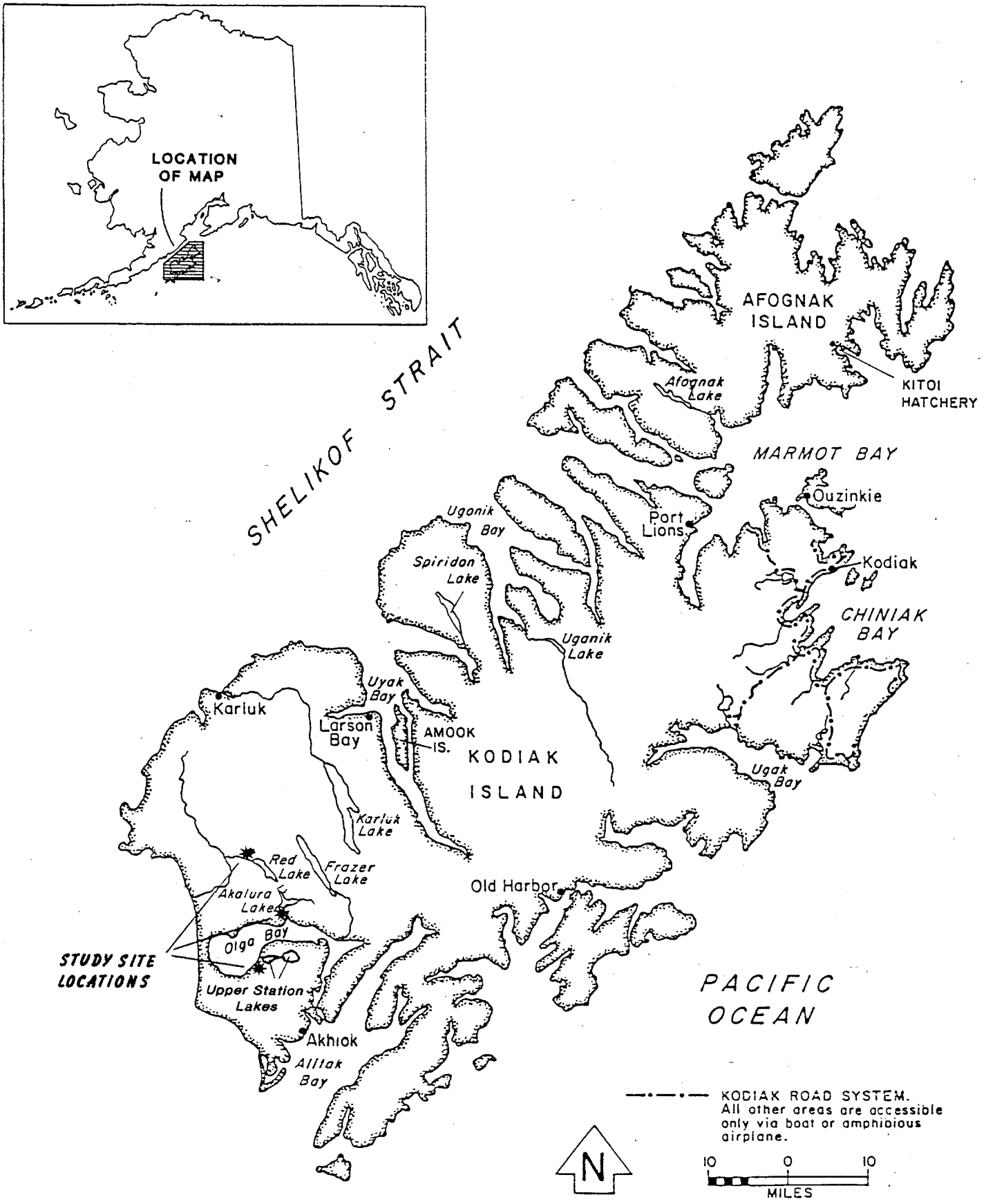

Figure 1. Location of Red, Akalura, and Upper Station lakes on the southern end of Kodiak Island.

Upper Station Lakes (57°04'N; 154°15'W) are located 14.4 km south of Akalura Lake. The upper lake is 6.0 km long and 2.0 km wide with a lake surface area of 7.9 million m^2. The mean depth of the upper lake is 26.2 m and it is classified as oligotrophic. The lower lake is 4.0 km long and up to 1.6 km wide with a mean depth of 2.0 m. The watershed drainage area is 40.1 km^2, and lake water residence time for the upper lake is 4.2 years.

METHODS

Hydroacoustic Instrumentation

The following equipment was utilized to conduct mobile surveys: (1) Biosonics® Model 105 portable echosounder equipped with single frequency of 420 kHz and a simultaneous 20/40 log R Time Varied Gain (TVG) range 1.25-125 m; (2) Biosonics Model 171 tape recorder interface (multiplex); (3) Portable TCD-D10PRO® digital audio tape recorder (DAT); (4) Tow-fin mounted dual beam (6-15 degrees) transducer; (5) Tektronix® Model 212 oscilloscope; (6) Biosonics Model 115 portable chart recorder; (7) Fluke® Model 8062A digital multimeter; and (8) Marsh-McBirney® flow meter.

The Model 105 echosounder, in conjunction with the dual beam transducer, produces sound waves that are transmitted through the water. Objects such as fish reflect the waves (or pulses) which are received as echoes by the sounder. Voltages (signals) are produced from the detected echoes and displayed in real time on the oscilloscope and as fish signals on a portable paper chart recorder. The voltages are recorded in digital format for later analysis on Dat® cassette tapes. This analysis is facilitated by the tape recorder interface. The oscilloscope is also used to measure calibration signals, which are recorded at the beginning, mid-way, and at the end of each survey. Finally, a digital

® Mention of commercial products and trade names does not constitute endorsement by the Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division.

multimeter is used to measure the power output of the echosounder. The echosounder, tape recorder interface, and chart recorder are powered by 12-volt batteries, while the Dat recorder and multimeter are powered by internal batteries.

Instrument Settings for Data Acquisition

The settings used with the Biosonics 105 echosounder were as follows: Receiver gain at 0 dB; ping rate at 5 pings per second; pulse width at 0.4 m/second; and TVG at 40 log (R). Calibration setting (Caltone) was set at -20 dB to produce a calibration signal of 3.5 volts at 10 ms.

Survey Design

Surveys consisted of collecting (recording) hydroacoustic data along transects that were orthogonal to the longitudinal axis of each lake. Transects were selected randomly for each lake from representative areas (basins). The number of transects was based on the size of the lake and number of delineated areas. Upper Station and Red lakes each had eight transects, and Akalura had six. Data were recorded along each transect once, and the survey was continued until all transects were complete. All surveys were conducted after dark, when juvenile salmon are distributed in the upper to middle part of the water column (Narver 1970; McDonald 1973; Eggers 1978; Simpson et al. 1981; Nunnallee 1983; Burczynski and Johnson 1986; Levy 1987). A 4.9-m Achilles® raft powered by a 30-hp outboard engine was utilized for the surveys. Survey speed along each transect was maintained at 1.5 m/sec and monitored by the use of a portable Marsh-McBirney flow meter. Transect direction was maintained by the use of flashing strobe lights at one end of each transect. Compass bearings were also used to maintain the course of each transect.

Hydroacoustic Data Analysis

Recorded data were analyzed by Biosonics, Inc. The analysis procedures were dependent on the occurrence of multiple targets and the relative fish density for each survey. In general, lakes with low fish densities with dispersed targets were analyzed using echo counting techniques. Lakes with dense, multiple targets were analyzed using echo integration techniques. The echo counting method is more tedious than the echo integration method, but in lakes with low densities it is more accurate (Thorne 1983). The specific steps in the echo counting and echo integration procedures are described in Kyle (1990).

In Red Lake during 1990 and 1991, densities of fish were too high for echo counting (Thorne 1990). Consequently, the data tapes were analyzed by echo integration using a BioSonics Model 221 Echo Signal Processor. The integration measurements were made within eight depth intervals between 2 and 50 m (reference transducer depth) and along each one-third transect. The integration values were scaled to estimates of fish density by echo counting techniques and duration-in-beam measurements in selected depths and transects where predominately individual fish targets could be resolved (Thorne 1988). The resulting densities in each strata were summed to determine an average density per unit surface area, then extrapolated to the area of the lake. The total lake area covered by the hydroacoustic survey was assumed to be 6,028,000 m^2.

In Upper Station Lake, low and dispersed fish densities in 1990 and 1991 allowed use of the echo counting technique. Echo counts were made within eight depth intervals from 2 m to the bottom along each one-third transect. Fish densities in each strata were summed to determine an average density per unit surface area, then extrapolated to the area of the lake. The total lake area covered by the hydroacoustic survey was assumed to be 7,085,000 m^2.

Finally, in Akalura Lake for the 1990 survey, the echo integration technique was used for data analysis. The data were scaled by regression against echo counts from selected lower density strata. Echo integration measurements were made along each one-min of transect and within six depth strata: 2.0-5, 5-9.5, 9.5-14, 14-18.5, 18.5-23, and 23-27.5 m. Fish densities in each strata were summed to determine an average density per unit surface area, then extrapolated to the area of the lake. The total lake area covered by the hydroacoustic survey was assumed to be 4,900,000 m^2. In 1991, data were analyzed by echo counts along each one-third transect and within six depth strata: 2.0-5, 5-9.5, 9.5-14, 14-18.5, 18.5-23, and 23-27.5 m.

Ground Truthing Technique

Townet sampling was used to calculate juvenile sockeye salmon population estimates for each lake by multiplying the proportion of sockeye salmon in combined townet catches by the total fish population estimate. Transect/strata variance and 95% confidence intervals for the juvenile sockeye population estimates were calculated using the formulae developed by Thorne and Thomas (1982).

Townet samples provided species composition, age composition, and size of juvenile sockeye salmon. The townet technique used was similar to that described by Gjernes (1979). The townet used measured 2 m x 2 m at the mouth and was 7.5 m in length. The body of the net was constructed of knotless nylon with three different mesh sizes (3.8 cm, 1.3 cm, 0.6 cm), and the cod-end was constructed of 0.3 cm knotless nylon. Two tow lines, each 91.5 m in length, were attached to the townet bridle, which was attached to the corner of each side of the net.

Tows were conducted at night when juvenile sockeye salmon are widely distributed in the pelagic area of the lake to minimize net avoidance and to assure random sampling. Towing was usually conducted on the night of each hydroacoustic survey; however, in

1992, townet samples were collected to obtain age, weight, and length (AWL) data without hydroacoustic surveys being conducted. Townetting was not conducted at Akalura Lake in 1992 because of the appearance of high net avoidance by sockeye fry and a resultant disproportionate catch of sticklebacks (*Gasterosteus sp.*) during the 1990 and 1991 surveys. Tow location and depth were determined by acoustic target locations from echograms and conducted in areas where high numbers of acoustic targets were observed. Townetting surveys were facilitated by the use of a 4.9-m Achilles raft powered by a 30-hp engine at a speed of approximately 1 m/s. A minimum of 3 tows, ranging from 20 to 30 minutes in duration per lake, were conducted during each survey.

The catch from each tow was sorted, counted, and recorded by species, and the total catch weight by species was measured to the nearest 0.1 g. When greater than 200 sticklebacks were captured, a random sample of 100 to 150 sticklebacks were counted and weighed together to determine mean fish weight. The total number of sticklebacks was calculated by dividing the total biomass by the average fish weight. In 1990, samples were inadvertently preserved in an improper dilution of ethyl alcohol and were unsuitable for size and age sampling. Juvenile sockeye salmon caught in 1991 were preserved in ethyl alcohol, which can result in a shrinkage of 20% (Patrick Shields[1], personal communication). These preserved samples were measured (nearest 1.0 mm), weighed (0.1 g), and the condition coefficient (K_D) calculated (Bagenal 1978). Ages were determined as described by Mosher (1969) from scale smears (mounted on glass slides) using a microfiche projector. In 1992, juvenile sockeye collected were sorted, measured for length, weight, and condition coefficient, and individually preserved in whirlpac containers and frozen. Juvenile sockeye less than 35 mm in length were considered newly emergent fry and were frozen after recording weight and count data.

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[1] Alaska Department of Fish and Game, Limnology Laboratory, 34828 Kalifornsky Beach Road, Suite B, Soldotna, Alaska 99669-3150.

RESULTS

Red Lake

The 30 September 1990 hydroacoustic survey in Red Lake revealed a population estimate of 7,227,742 ± 1,148,222 juvenile fish rearing in the pelagic area (Table 1). Area A (Figure 2), represented by Transects 1 and 2 located at the west end of the lake, had the highest density and population of fish (2,792,104), while Area D (Transects 7 and 8) located at the east end of the lake, had the lowest density and fish population (1,102,778). Population estimates for Areas B and C were 1,448,571 and 1,884,289 fish, respectively. Individual transect population estimates ranged from 1,544,060 for Transect 2 to 342,004 for Transect 8 (Table 2). The horizontal distribution of fish for all transects combined revealed 50.6% of the targets were located in the northeast section of the lake and 30.9% and 18.5% were found in the middle and southwest sections, respectively (Table 3). The fish were distributed vertically from 2 to 50 m (Table 4). The higher densities (>15%) were in the 2-5, 5-9, 9-13.5, and 27-35 m depth range intervals.

Townetting on 30 September 1990 in Red Lake resulted in a catch of 20 sockeye salmon juveniles that represented 1.4% of the total catch (Table 5). The remainder of the catch comprised 1,452 sticklebacks (Table 6). The sockeye catch per unit effort (CPUE) was 0.22. When applying the sockeye composition to the total population estimate determined from hydroacoustics, a sockeye population of 101,220 ± 16,000 is estimated.

The population estimate based on the 07 October 1991 hydroacoustic survey in Red Lake was 9,430,782 ± 2,903,502 juvenile fish (Table 7). Similar to the 1990 survey, Area A (Figure 2), represented by Transects 1 and 2 located at the west end of the lake, had the highest density and population of fish (4,333,388), while Area D (Transects 7 and 8), located at the east end of the lake, had the lowest density and fish population

Table 1. Densities and population estimates of juvenile fish rearing in Red Lake by transect based on the 30 September 1990 hydroacoustic survey.

Transect	Mean fish density (no./1000 m^2)	Area (X 1000 m^2) transect	Area (X 1000 m^2) total	Weighted mean fish density (no./1000 m^2)	Variance	Fish population	Variance
1	1367.33	918					
2	1676.00	917	1,835	1521.6	2.38E+04	2,792,104	8.0E+10
3	1409.00	655					
4	775.33	678	1,333	1086.7	1.00E+05	1,448,571	1.8E+11
5	1017.00	794					
6	1292.67	833	1,627	1158.1	1.90E+04	1,884,289	5.0E+10
7	1,015.00	754					
8	706.00	478	1,232	895.1	2.27E+04	1,102,778	3.4E+10
					Total	7,227,742	3.4E+11
				95% confidence interval (+/-)		1,148,222	

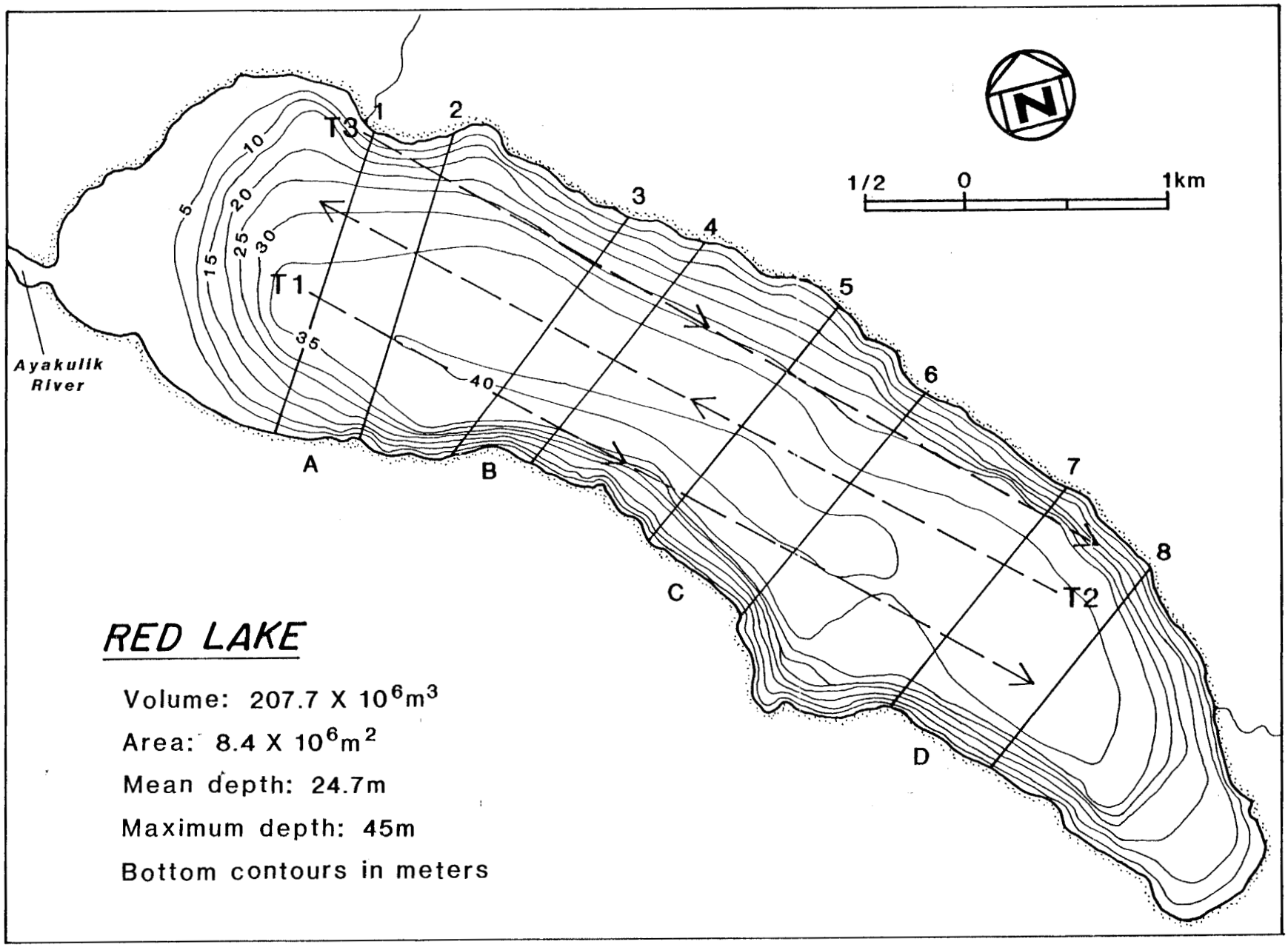

Figure 2. Morphometric map of Red Lake showing hydroacoustic areas (A-D), transects (1-8), and townetting locations (T1-T3).

Table 2. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 30 September 1990 survey of Red Lake.

		Depth Interval (m)										
Transect (T)	Section	2-5	5-9	9-13.5	13.5-18	18-22.5	22.5-27	27-35	35-50	Total	Area (x10^3 m^2)	Pop. Est.
1	Northeast	82.0	90.0	171.0	270.0	384.0	525.0	306.0	0.0	1,828.0	303	553,884
	Middle	155.0	83.0	125.0	104.0	70.0	239.0	390.0	6.0	1,172.0	307	359,804
	Southwest	71.0	59.0	43.0	35.0	144.0	378.0	362.0	10.0	1,102.0	308	339,416
Total (T-1)		308.0	232.0	339.0	409.0	598.0	1,142.0	1,058.0	16.0	4,102.0	918	1,253,104
2	Northeast	486.0	456.0	494.0	608.0	449.0	401.0	540.0	6.0	3,440.0	307	1,056,080
	Middle	116.0	91.0	150.0	178.0	60.0	115.0	294.0	50.0	1,054.0	312	328,848
	Southwest	77.0	18.0	19.0	16.0	27.0	107.0	227.0	43.0	534.0	298	159,132
Total (T-2)		679.0	565.0	663.0	802.0	536.0	623.0	1,061.0	99.0	5,028.0	917	1,544,060
3	Northeast	228.0	284.0	286.0	281.0	427.0	490.0	733.0	10.0	2,739.0	209	572,451
	Middle	35.0	73.0	184.0	180.0	39.0	53.0	357.0	43.0	964.0	223	214,972
	Southwest	42.0	15.0	12.0	9.0	14.0	42.0	325.0	65.0	524.0	223	116,852
Total (T-3)		305.0	372.0	482.0	470.0	480.0	585.0	1,415.0	118.0	4,227.0	655	904,275

Table 2 continued. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 30 September 1990 survey of Red Lake.

Transect (T)	Section	Depth Interval (m) 2-5	5-9	9-18	18-27	27-36	36-45	45-54	54-69	Total	Area (x10^3 m^2)	Pop. Est.
4	Northeast	105.0	292.0	260.0	157.0	54.0	47.0	126.0	4.0	1,045.0	220	229,900
	Middle	29.0	90.0	153.0	115.0	48.0	36.0	222.0	49.0	742.0	234	173,628
	Southwest	73.0	42.0	79.0	52.0	25.0	37.0	157.0	74.0	539.0	224	120,736
Total (T-4)		207.0	424.0	492.0	324.0	127.0	120.0	505.0	127.0	2,326.0	678	524,264
5	Northeast	381.0	648.0	468.0	93.0	20.0	23.0	22.0	0.0	1,655.0	264	436,920
	Middle	172.0	267.0	205.0	105.0	22.0	20.0	147.0	47.0	985.0	268	263,980
	Southwest	24.0	44.0	80.0	50.0	16.0	25.0	126.0	46.0	411.0	262	107,682
Total (T-5)		577.0	959.0	753.0	248.0	58.0	68.0	295.0	93.0	3,051.0	794	808,582
6	Northeast	866.0	335.0	284.0	72.0	50.0	33.0	78.0	10.0	1,728.0	279	482,112
	Middle	117.0	298.0	249.0	148.0	40.0	72.0	395.0	85.0	1,404.0	284	398,736
	Southwest	35.0	113.0	219.0	70.0	34.0	45.0	156.0	74.0	746.0	270	201,420
Total (T-6)		1,018.0	746.0	752.0	290.0	124.0	150.0	629.0	169.0	3,878.0	833	1,082,268

Table 2 continued. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 30 September 1990 survey of Red Lake.

Transect (T)	Section	Depth Interval (m) 2-5	5-9	9-18	18-27	27-36	36-45	45-54	54-69	Total	Area (x10^3 m^2)	Pop. Est.
7	Northeast	183.0	297.0	133.0	37.0	27.0	21.0	37.0	2.0	737.0	247	182,039
	Middle	310.0	352.0	327.0	66.0	43.0	19.0	225.0	38.0	1,380.0	251	346,380
	Southwest	217.0	323.0	150.0	56.0	30.0	34.0	115.0	3.0	928.0	256	237,568
Total (T-7)		710.0	972.0	610.0	159.0	100.0	74.0	377.0	43.0	3,045.0	754	765,987
8	Northeast	297.0	355.0	82.0	42.0	20.0	28.0	33.0	0.0	857.0	167	143,119
	Middle	154.0	299.0	201.0	176.0	25.0	16.0	14.0	0.0	885.0	161	142,485
	Southwest	51.0	92.0	75.0	36.0	27.0	20.0	74.0	1.0	376.0	150	56,400
Total (T-8)		502.0	746.0	358.0	254.0	72.0	64.0	121.0	1.0	2,118.0	478	342,004
Total All Transects		4,306.0	5,016.0	4,449.0	2,956.0	2,095.0	2,826.0	5,461.0	666.0	27,775.0	6,027	7,224,544

Table 3. Horizontal distribution of the estimated population by lake section for the 30 September 1990 survey of Red Lake.

Section	Population (Number)	Distribution (Percent)
Northeast	3,656,505	50.6
Middle	2,228,833	30.9
Southwest	1,339,206	18.5
Total	7,224,544	100.0

Table 4. Vertical distribution of fish density by depth strata for the 30 September 1990 survey of Red Lake.

Depth (m)	Density (#/1000 m^2)	Percent of Total
2 - 5	4,306.0	15.5
5 - 9	5,016.0	18.1
9 - 13.5	4,449.0	16.0
13.5 - 18	2,956.0	10.6
18 - 22.5	2,095.0	7.5
22.5 - 27	2,826.0	10.2
27 - 35	5,461.0	19.7
35 - 50	666.0	2.4
Total	27,775.0	100.0

Table 5. Tow net sampling results, total population estimates and juvenile sockeye salmon estimates for surveys conducted at Red, Akalura and Upper Station Lakes, 1990 - 1992.

Lake	Date Surveyed	Tows Conducted	Total Tow Time (minutes)	Sockeye Catch			Total Population		Sockeye Population	
				number\a	CPUE\b	% of total	number (x 10^6)	95% C. I. (x 10^6)	number	95% C. I.
Red	30-Sep-90	3	90	20	0.22	1.4	7.23	1.15	101,220	16,000
	12-May-91	3	82	34	0.41	2.7	na	na	na	na
	06-Oct-91	3	90	91	1.01	6.7	9.43	2.9	631,810	194,779
	23-Sep-92	3	92	62	0.67	1.9	na	na	na	na
	24-Sep-92	3	120	149	1.24	na	na	na	na	na
Upper Station	28-Sep-90	3	91	174	1.91	30.5	3.84	0.47	1,171,200	142,723
	08-May-91	3	90	14	0.16	1.0	na	na	na	na
	04-Oct-91	3	94	160	1.70	9.8	3.99	0.56	391,020	54,328
	21-Sep-92	3	93	275	2.96	33.6	na	na	na	na
Akalura	29-Sep-90	3	70	237	3.39	5.3	3.95	0.79	209,350	42,068
	11-May-91	3	72	54	0.75	12.2	na	na	na	na
	05-Oct-91	3	70	147	2.10	1.4	3.17	0.54	44,380	20,846

\a May samples include newly emergent sockeye fry.

\b catch per unit effort.

na-not available (hydroacoustic surveys were not conducted during this period).

Table 6. Tow net catch by species for Red, Upper Station, and Akalura Lakes, September 1990.

Loc.	Date	Tow				Catch Numbers				Catch Weight (g)		Mean Fish Weight (g)	
		No.	Time (Military)		Total #	Sockeye		Stickleback					
			Start	End	Minutes	No.	%	No.	%	Sockeye	Stickleback	Sockeye	Stickleback
Red Lake													
	30-Sep-90	1	2256	2326	30	7	1.9	370	98.1	16.1	378.2	2.3	1.0
	30-Sep-90	2	2353	23	30	3	0.5	569	99.5	3.8	490.6	1.3	0.9
	01-Oct-90	3	46	116	30	10	1.9	513	98.1	15.1	414.7	1.5	0.8
Total						20	1.4	1,452	98.6				
Akalura Lake													
	29-Sep-90	1	2209	2239	30	114	4.3	2,545	95.7	186.3	2370.5	1.6	0.9
	29-Sep-90	2	2304	2324	20	57	6.1	874	93.9	107.3	882.1	1.9	1.0
	29-Sep-90	3	2347	0007	20	66	7.3	833	92.7	140.0	820.0	2.1	1.0
Total						237	5.3	4,252	94.7				
Upper Station Lake													
	28-Sep-90	1	2233	2303	30	70	19.9	282	80.1	104.6	1025.0	1.5	3.6
	28-Sep-90	2	2328	2359	31	68	44.4	85	55.6	192.2	369.8	2.8	4.4
	29-Sep-90	3	0210	0240	30	36	54.5	30	45.5	93.5	116.0	2.6	3.9
Total						174	30.5	397	69.5				

Table 7. Densities and population estimates of juvenile fish rearing in Red Lake by transect based on the 7 October 1991 hydroacoustic survey.

Transect	Mean fish density (no./1000 m^2)	Area (X 1000 m^2) transect	Area (X 1000 m^2) total	Weighted mean fish density (no./1000 m^2)	Variance	Fish population	Variance
1	3461.33	779					
2	1793.00	913	1,692	2561.1	6.91E+05	4,333,388	2.0E+12
3	1886.00	768					
4	1816.67	709	1,477	1852.7	1.20E+03	2,736,465	2.6E+09
5	1473.00	713					
6	855.67	748	1,461	1156.9	9.52E+04	1,690,288	2.0E+11
7	546.67	699					
8	411.00	702	1,401	478.7	4.60E+03	670,642	9.0E+09
					Total	9,430,782	2.2E+12
				95% confidence interval (+/-)		2,903,502	

(670,642). Population estimates for Areas B and C were 2,736,465 and 1,690,288 fish, respectively. Individual transect population estimates ranged from 2,690,127 for Transect 1 to 279,381 for Transect 8 (Table 8). The horizontal distribution of fish for all transects combined resulted in a relatively even distribution among the three sections with 35.0%, 33.3%, and 31.7% of the targets located in the southwest, middle, and northeast sections, respectively (Table 9). The highest proportion of fish was distributed vertically in the 5-9 and 9-13.5 m depth ranges (Table 10). Few fish were observed below 35 m (0.8%). Townetting on 12 May 1991 in Red Lake resulted in a catch of 34 sockeye salmon juveniles (including 12 newly emergent fry) that comprised 2.7% of the total catch (*See* Table 5). The remainder of the catch comprised 1,228 stickleback and 1 Dolly Varden char (*Salvelinus malma*) (Table 11). The sockeye CPUE was 0.41. Of the total sockeye catch, 35.3% were age-0 juveniles, 17.6% age-1 juveniles, and 47.1% age-2 juveniles (Table 12). The mean weight, length, and condition coefficient of age-0 fish was 0.2 g, 29 mm, and 0.83 K_D, respectively. The mean weight, length, and condition coefficient of age-1 fish was 2.4 g, 69 mm, and 0.74 K_D, respectively. The mean weight, length, and condition coefficient of age-2 fish was 6.0 g, 95 mm, and 0.69 K_D, respectively.

Townetting on 06 October 1991 in Red Lake resulted in a catch of 91 sockeye salmon juveniles that represented 6.7% of the total catch (*See* Table 5). The remainder of the catch comprised 1,277 sticklebacks (Table 13). The sockeye CPUE was 1.01. The sockeye population determined from hydroacoustics and townetting was estimated to be 631,810 + 194,779. Of the total sockeye catch, 29.7% were age-0 and 70.3% age-1 juveniles (Table 12). The mean weight, length, and condition coefficient of age-0 fish was 1.2 g, 51 mm, and 0.85 K_D, respectively. The mean weight, length, and condition coefficient of age-1 fish was 4.4 g, 81 mm, and 0.81 K_D, respectively. (Weight, length, and condition information is calculated from measurements of fish preserved for over a year in alcohol.)

Table 8. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 07 October 1991 survey of Red Lake.

Transect (T)	Section	Depth Interval (m) 2-5	5-9	9-13.5	13.5-18	18-22.5	22.5-27	27-35	35-50	Total	Area (x10^3 m^2)	Pop. Est.
1	Northeast	43.0	133.0	1,581.0	580.0	283.0	321.0	131.0	0.0	3,072.0	270	829,440
	Middle	59.0	339.0	1,287.0	874.0	488.0	268.0	334.0	0.0	3,649.0	270	985,230
	Southwest	663.0	1,041.0	899.0	510.0	308.0	131.0	111.0	0.0	3,663.0	239	875,457
Total (T-1)		765.0	1,513.0	3,767.0	1,964.0	1,079.0	720.0	576.0	0.0	10,384.0	779	2,690,127
2	Northeast	153.0	347.0	468.0	223.0	201.0	250.0	196.0	0.0	1,838.0	315	578,970
	Middle	82.0	141.0	285.0	280.0	332.0	276.0	351.0	0.0	1,747.0	320	559,040
	Southwest	188.0	277.0	544.0	294.0	134.0	142.0	214.0	1.0	1,794.0	278	498,732
Total (T-2)		423.0	765.0	1,297.0	797.0	667.0	668.0	761.0	1.0	5,379.0	913	1,636,742
3	Northeast	175.0	499.0	943.0	335.0	162.0	122.0	176.0	1.0	2,413.0	248	598,424
	Middle	72.0	290.0	278.0	81.0	104.0	147.0	236.0	25.0	1,233.0	265	326,745
	Southwest	102.0	242.0	468.0	372.0	466.0	190.0	136.0	36.0	2,012.0	255	513,060
Total (T-3)		349.0	1,031.0	1,689.0	788.0	732.0	459.0	548.0	62.0	5,658.0	768	1,438,229

Table 8 continued. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 07 October 1991 survey of Red Lake.

Transect (T)	Section	Depth Interval (m) 2-5	5-9	9-18	18-27	27-36	36-45	45-54	54-69	Total	Area (x10^3 m^2)	Pop. Est.
4	Northeast	325.0	735.0	262.0	73.0	69.0	59.0	60.0	0.0	1,583.0	243	384,669
	Middle	151.0	602.0	556.0	158.0	111.0	132.0	224.0	45.0	1,979.0	250	494,750
	Southwest	198.0	713.0	217.0	151.0	259.0	128.0	185.0	37.0	1,888.0	216	407,808
Total (T-4)		674.0	2,050.0	1,035.0	382.0	439.0	319.0	469.0	82.0	5,450.0	709	1,287,227
5	Northeast	498.0	595.0	327.0	88.0	98.0	75.0	36.0	0.0	1,717.0	213	365,721
	Middle	28.0	148.0	410.0	282.0	141.0	152.0	219.0	55.0	1,435.0	250	358,750
	Southwest	142.0	242.0	142.0	87.0	171.0	159.0	280.0	44.0	1,267.0	250	316,750
Total (T-5)		668.0	985.0	879.0	457.0	410.0	386.0	535.0	99.0	4,419.0	713	1,041,221
6	Northeast	165.0	214.0	117.0	18.0	15.0	20.0	26.0	0.0	575.0	232	133,400
	Middle	29.0	96.0	146.0	85.0	74.0	103.0	283.0	31.0	847.0	266	225,302
	Southwest	140.0	412.0	150.0	53.0	98.0	84.0	190.0	18.0	1,145.0	250	286,250
Total (T-6)		334.0	722.0	413.0	156.0	187.0	207.0	499.0	49.0	2,567.0	748	644,952

Table 8 continued. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 07 October 1991 survey of Red Lake.

Transect (T)	Section	Depth Interval (m) 2-5	5-9	9-18	18-27	27-36	36-45	45-54	54-69	Total	Area (x10^3 m^2)	Pop. Est.
7	Northeast	49.0	14.0	14.0	24.0	23.0	30.0	72.0	0.0	226.0	217	49,042
	Middle	7.0	80.0	95.0	93.0	59.0	99.0	141.0	0.0	574.0	241	138,334
	Southwest	209.0	151.0	154.0	89.0	83.0	78.0	76.0	0.0	840.0	241	202,440
Total (T-7)		265.0	245.0	263.0	206.0	165.0	207.0	289.0	0.0	1,640.0	699	389,816
8	Northeast	24.0	27.0	25.0	24.0	20.0	37.0	35.0	0.0	192.0	236	45,312
	Middle	20.0	21.0	32.0	10.0	15.0	32.0	37.0	0.0	167.0	245	40,915
	Southwest	163.0	89.0	141.0	72.0	151.0	171.0	87.0	0.0	874.0	221	193,154
Total (T-8)		207.0	137.0	198.0	106.0	186.0	240.0	159.0	0.0	1,233.0	702	279,381
Total All Transects		3,685.0	7,448.0	9,541.0	4,856.0	3,865.0	3,206.0	3,836.0	293.0	36,730.0	6,031	9,407,695

Table 9. Horizontal distribution of estimated population by lake section for the 07 October 1991 survey of Red Lake.

Section	Population (Number)	Distribution (Percent)
Northeast	2,984,978	31.7
Middle	3,129,066	33.3
Southwest	3,293,651	35.0
Total	9,407,695	100.0

Table 10. Vertical distribution of fish density by depth strata for the 07 October 1991 survey of Red Lake.

Depth (m)	Density (#/1000 m^2)	Percent of Total
2 - 5	3,685.0	10.0
5 - 9	7,448.0	20.3
9 - 13.5	9,541.0	26.0
13.5 - 18	4,856.0	13.2
18 - 22.5	3,865.0	10.5
22.5 - 27	3,206.0	8.7
27 - 35	3,836.0	10.4
35 - 50	293.0	0.8
Total	36,730.0	100.0

Table 11. Tow net catch by species, in numbers and biomass, for Red, Upper Station, and Akalura Lakes, May 1991.

Loc. / Date	Tow No.	Tow Time (Military) Start	Tow Time (Military) End	Tow Total Min.	Catch Numbers Sockeye/1 No.	Catch Numbers Sockeye/1 %	Catch Numbers Stickleback No.	Catch Numbers Stickleback %	Catch Numbers Other*	Catch Weight (g) Sockeye/1	Catch Weight (g) Stickleback	Catch Weight (g) Other	Mean Fish Weight (g) Sockeye/1	Mean Fish Weight (g) Stickleback	Mean Fish Weight (g) Other	Comments
Red Lake																
12-May-91	1	1316	1341	25	10	1.9	521	97.9	1	59.2	1,402.5	46.1	5.9	2.7	46.1	2 YOY sockeye caught
12-May-91	2	1408	1435	27	2	0.7	277	99.3	0	8.3	840.5	0.0	4.1	3.0	-	6 YOY sockeye caught
12-May-91	3	1516	1546	30	10	2.3	430	97.7	0	75.4	1,397.5	0.0	7.5	3.3	-	4 YOY sockeye caught
Total:				82	22	1.8	1,228	98.2	1	-	-	-	-	-	-	12 = 34 total (2.7%)
Akalura Lake																
11-May-91	1	0020	0040	20	6	7.7	72	92.3	0	13.7	114	0.0	2.3	1.6	-	1 YOY sockeye caught
11-May-91	2	0116	0144	28	33	13.9	204	86.1	0	55.5	269.0	0.0	1.7	1.3	-	2 YOY sockeye caught
11-May-91	3	0207	0231	24	11	9.0	111	91.0	0	18.0	129.6	0.0	1.6	1.2	-	1 YOY sockeye caught
Total:				72	50	11.4	387	88.6	0	-	-	-	-	-	-	4 = 54 total (12.2%
U. Station Lake																
08-May-91	1	0012	0042	30	1	14.3	6	85.7	0	19.3	29.8	0.0	19.3	5.0	-	1 YOY sockeye caught
08-May-91	2	0115	0145	30	3	1.0	293	99.0	0	36.8	1,349.0	0.0	12.3	4.7	-	
08-May-91	3	0235	0305	30	5	0.5	1,054	99.5	0	48.2	4,860.0	0.0	9.6	4.6	-	4 YOY sockeye caught
Total:				90	9	0.7	1,353	99.3	0	-	-	-	-	-	-	5 = 14 total (1.0%)

1/ Young-of-year sockeye fry not included in count or biomass numbers; * Dolly Varden char

Table 12. Age, size and condition coefficient of juvenile sockeye salmon collected by tow netting in Red, Akalura and Upper Station Lakes, 1991.

Lake	Date Sampled	No. Sampled	Age	Age Composition (%)	Mean Weight (g)	Mean Length (mm)	Condition Coefficient (K)
Red	12 May	12	0	35.3	0.2	29	0.83
		6	1	17.6	2.4	69	0.74
		16	2	47.1	6.0	95	0.69
		34					
Akalura	11 May	3	0	6.8	0.2	29	0.79
		24	1	54.5	1.0	50	0.78
		17	2	38.6	2.4	68	0.74
		44 \a					
U. Station	08 May	4	0	30.8	0.3	31	0.87
		2	1	15.4	3.3	73	0.87
		7	2	53.8	10.4	109	0.79
		13 \b					
Red	06 October	27	0	29.7	1.2	51	0.85
		64	1	70.3	4.4	81	0.81
		91					
Akalura	05 October	54	0	36.7	1.4	52	0.95
		93	1	63.3	3.8	74	0.93
		147					
U. Station	04 October	116	0	72.5	1.7	56	0.85
		44	1	27.5	7.0	91	0.91
		160 \c					

\a 10 of 54 sockeye caught were not sampled for AWL data.

\b 1 of 14 sockeye caught was not sampled for AWL data.

\c an additional juvenile sockeye was sampled for AWL data that was not accounted for in the field data (Table 13).

Table 13. Tow net catch by species for Red, Upper Station, and Akalura Lakes, October 1991.

Loc.	Date	Tow No.	Tow Time (Military) Start	Tow Time (Military) End	Total Min.	Catch Numbers Sockeye No.	Sockeye %	Stickleback No.	Stickleback %	DV*	Catch Weight (g) Sockeye	Stickleback	DV*	Mean Fish Weight (g) Sockeye	Stickleback	DV*
Upper Station																
	04-Oct-91	1	2130	2203	33	11	1.3	835	98.7	0	28.5	2,606.7		2.6	3.1	
	04-Oct-91	2	2231	2302	31	72	14.3	432	85.7	0	218.3	1,360.6		3.0	3.1	
	04-Oct-91	3	2328	2358	30	76	26.3	213	73.7	0	319.4	722.7		4.2	3.4	
Total						159	9.7	1,480	90.3							
Akalura Lake																
	05-Oct-91	1	2156	2221	25	74	3.9	1,807	96.1	0	232.0	1,698.4		3.1	0.9	
	05-Oct-91	2	2245	2305	20	24	1.6	1,466	98.4	3	67.3	1,378.3	147.7	2.8	0.9	49.2
	05-Oct-91	3	2345	0010	25	49	0.6	7,492	99.4	0	156.6	6,742.5		3.3	0.9	
Total						147	1.3	10,765	98.7	3						
Red Lake																
	06-Oct-91	1	2157	2227	30	56	10.9	457	89.1	0	224.9	593.7		4.0	1.3	
	06-Oct-91	2	2245	2315	30	22	3.6	593	96.4	0	103.0	723.0		4.7	1.2	
	07-Oct-91	3	0007	0037	30	13	5.4	227	94.6	0	48.6	317.7		3.7	1.4	
Total						91	6.7	1,277	93.3							

*DV = Dolly Varden.

Townetting on 23 September 1992 in Red Lake resulted in a catch of 62 sockeye salmon juveniles that comprised 1.9% of the total catch (*See* Table 5). The remainder of the catch comprised 3,190 sticklebacks, 1 Dolly Varden char, and 1 coho salmon (*Oncorhynchus kisutch*) (Table 14). The sockeye CPUE was 0.67. Of the total sockeye catch, 75.8% were age-0 and 24.2% age-1 juveniles (Table 15). The mean weight, length, and condition coefficient of age-0 sockeye salmon was 2.6 g, 70 mm, and 0.74 K_D, respectively. The mean weight, length, and condition coefficient of age-1 sockeye salmon was 9.0 g, 102 mm, and 0.84 K_D, respectively.

Townetting on 24 September 1992 in Red Lake resulted in a catch of 149 sockeye juveniles (*See* Table 5). The remainder of the catch was discarded and not enumerated. The sockeye CPUE was 1.24. Of the total sockeye catch, 60.4% were age-0 and 39.6% age-1 juveniles (Table 15). The mean weight, length, and condition coefficient of age-0 sockeye salmon was 2.6 g, 67 mm, and 0.84 K_D, respectively. The mean weight, length, and condition coefficient of age-1 sockeye salmon was 7.4 g, 92 mm, and 0.83 K_D, respectively.

Akalura Lake

Results of the 29 September 1990 hydroacoustic survey showed an estimated population estimate of 3,950,101 $\pm$ 794,717 juvenile fish in Akalura Lake (Table 16). Area C, represented by Transects 5 and 6 located in the north arm of the lake, had the highest density and population of fish (1,720,390), while population estimates for Areas A and B (Transects 1-4) were 746,705 and 1,483,006, respectively (Figure 3). Individual transect population estimates ranged from 1,080,362 for Transect 5 to 138,212 for Transect 1 (Table 17). The horizontal distribution of fish for all transects combined revealed 57.6% of the targets were located along north-south Transects 1-4 (Areas A and B), and 42.5% located along east-west Transects 5 and 6

Table 14. Tow net catch by species for Red and Upper Station Lakes, 1992.

Loc.	Date	Tow				Catch Numbers						Catch Weight (g)			
		No.	Time (Military) Start	End	Total Min.	Sockeye No.	Sockeye %	Stickleback No.	Stickleback %	DV*	Coho	Sockeye	Stickleback	DV*	Coho
Red Lake															
	23-Sep-92	1	2210	2242	30	10	3.2	304	96.2	1	1	47.0	692.0	0	0.7
	23-Sep-92	2	2303	2335	32	30	3.0	968	97.0	0	0	79.2	1,972.0	0	0
	24-Sep-92	3	0003	0033	30	22	1.1	1,918	98.9	0	0	135.0	1,898.0	0	0
Total						62	1.9	3,190	98.0	1	1	-	-	-	-
Red Lake															
	24-Sep-92	1	2120	2200	40	84	nd	nd	nd	nd	nd	428.4	nd	nd	nd
	24-Sep-92	2	2210	2250	40	22	nd	nd	nd	nd	nd	118.8	nd	nd	nd
	24-Sep-92	3	2305	2345	40	43	nd	nd	nd	nd	nd	147.5	nd	nd	nd
Total						149	nd	nd	nd	nd	nd	-	nd	nd	nd
Upper Station															
	21-Sep-92	1	2130	2202	28	122	28.6	304	71.4	0	0	500.2	284.5	0	0
	21-Sep-92	2	2224	2255	31	49	26.6	135	73.4	0	0	205.8	470.7	0	0
	21-Sep-92	3	2324	2358	34	104	50.0	104	50.0	0	0	434.3	114.1	0	0
Total						275	33.6	543	66.4	0	0	-	-	-	-

*DV = Dolly Varden.

nd = no data

Table 15. Age, size and condition coefficient of juvenlie sockeye salmon collected by tow netting at Red, and Upper Station Lakes, 1992.

Lake	Date Sampled	No. Sampled	Age	Age Composition (%)	Mean Weight (g)	Mean Length (mm)	Condition Coefficient (K)
Red	23 September	47	0	75.8	2.6	70	0.74
		15	1	24.2	9.0	102	0.84

		62					
Red	24 September	90	0	60.4	2.6	67	0.84
		59	1	39.6	7.4	92	0.83

		149					
U. Station	21 September	213	0	77.5	2.9	67	0.89
		62	1	22.5	8.4	90	1.03

		275					

Table 16. Densities and population estimates of juvenile fish rearing in Akalura Lake by transect based on the 29 September 1990 hydroacoustic survey.

Transect	Mean fish density (no./1000 m^2)	Area (X 1000 m^2) transect	Area (X 1000 m^2) total	Weighted mean fish density (no./1000 m^2)	Variance	Fish population	Variance
1	154.60	612					
2	640.56	1,018	1,630	458.1	5.54E+04	746,705	1.5E+11
3	803.30	948					
4	847.80	851	1,799	824.4	4.94E+02	1,483,006	1.6E+09
5	1239.30	872					
6	1066.20	600	1,472	1168.7	7.24E+03	1,720,390	1.6E+10
					Total	3,950,101	1.64E+11
				95% confidence interval (+/-)		794,717	

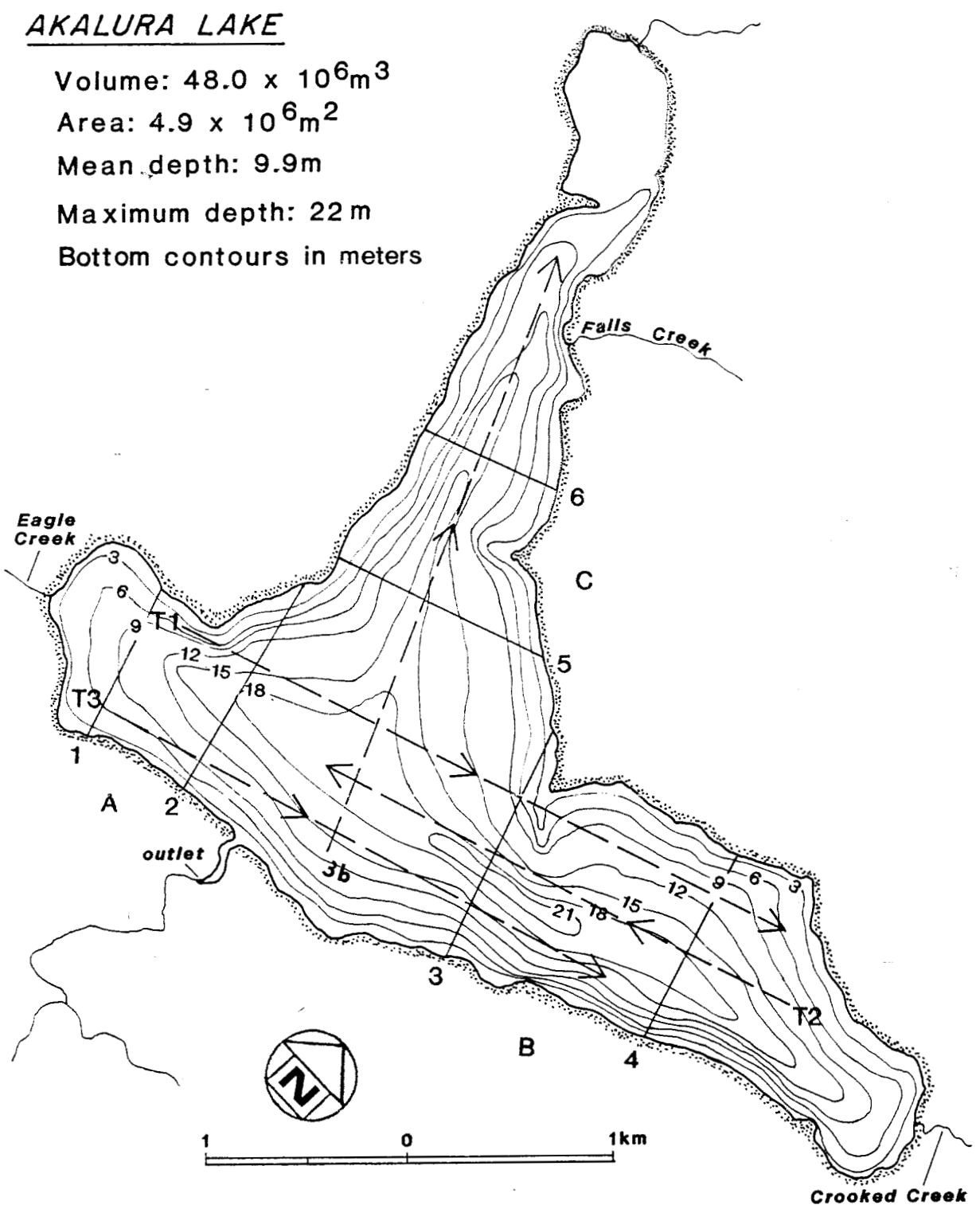

Figure 3. Morphometric map of Akalura Lake showing hydroacoustic areas (A-C), transects (1-6), and townetting locations (T1-T3a, b) (T3a for 1990 and T3b for 1991).

Table 17. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 29 September 1990 survey of Akalura Lake.

Transect (T)	Section	Depth Interval (m) 2-5	5-9.5	9.5-14	14-18.5	18.5-23	23-27.5	Total	Area (x10^3 m^2)	Pop. Est.
1	North	311.7	18.9	0.0	0.0	0.0	0.0	330.6	302	99,850
	Middle	105.9	27.3	0.0	0.0	0.0	0.0	133.2	288	38,362
	South	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22	0
Total (T-1)		417.6	46.2	0.0	0.0	0.0	0.0	463.8	612	138,212
2	North	392.2	32.7	0.0	0.0	0.0	0.0	424.9	323	137,239
	Middle	716.7	266.5	47.8	2.0	0.0	0.0	1,033.0	297	306,802
	South	246.4	106.1	201.9	215.4	0.0	0.0	769.8	398	306,367
Total (T-2)		1,355.4	405.2	249.6	217.4	0.0	0.0	2,227.7	1,018	750,409
3	North	61.3	251.1	173.1	158.7	38.8	0.0	683.0	293	200,115
	Middle	73.5	82.1	118.9	810.8	140.6	0.0	1,225.8	289	354,253
	South	139.9	204.4	28.3	105.3	23.3	0.0	501.2	366	183,454
Total (T-3)		274.6	537.6	320.3	1,074.8	202.7	0.0	2,410.0	948	737,822

Table 17 continued. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 29 September 1990 survey of Akalura Lake.

Transect (T)	Section	Depth Interval (m) 2-5	5-9.5	9.5-14	14-18.5	18.5-23	23-27.5	Total	Area (x10^3 m^2)	Pop. Est.
4	North	353.9	663.7	398.4	28.3	0.0	0.0	1,444.4	268	387,099
	Middle	101.0	131.8	219.4	144.4	0.0	0.0	596.6	289	172,420
	South	260.7	36.7	71.1	134.1	0.0	0.0	502.5	294	147,741
Total (T-4)		715.6	832.3	688.9	306.8	0.0	0.0	2,543.5	851	707,260
5	East	301.1	802.7	128.3	0.0	0.0	0.0	1,232.1	299	368,389
	Middle	469.1	672.1	315.8	0.0	0.0	0.0	1,457.0	286	416,702
	West	290.2	465.6	273.0	0.0	0.0	0.0	1,028.8	287	295,271
Total (T-5)		1,060.4	1,940.3	717.2	0.0	0.0	0.0	3,717.9	872	1,080,362
6	East	751.8	448.8	11.5	0.0	0.0	0.0	1,212.1	213	258,177
	Middle	348.9	807.7	247.0	0.0	0.0	0.0	1,403.5	198	277,901
	West	316.8	255.2	10.9	0.0	0.0	0.0	583.0	189	110,183
Total (T-6)		1,417.5	1,511.7	269.4	0.0	0.0	0.0	3,198.6	600	646,261
Lake Total		5,241.2	5,273.4	2,245.3	1,598.9	202.7	0.0	14,561.5	4,901	4,060,327

(Area C) (Table 18). Within the north-south transects, 35.3% of the fish were located in the north section of the lake and 37.4% and 27.3% were found in the middle and south sections, respectively. Within the east-west transects, 36.3% of the fish were observed in the east section, while 23.5% and 42.5% were observed in the middle and west sections, respectively. The fish were distributed vertically from depths of 2 to 23 m with highest densities found in the 2-5 m (36.0%) and 5-9.5 m (36.2%) depth ranges (Table 19). The lowest densities were recorded in the 18.5-23 m range (1.4%).

Townetting on 29 September 1990 in Akalura Lake resulted in a catch of 237 sockeye salmon juveniles that equated to 5.3% of the total catch (*See* Table 5). The remainder of the catch comprised 4,252 sticklebacks (*See* Table 6). The sockeye CPUE was 3.39. Based on townetting proportions, the juvenile sockeye population was 209,350 $\pm$ 42,068.

The 05 October 1991 hydroacoustic survey in Akalura Lake revealed a population estimate of 3,171,881 $\pm$ 540,383 juvenile fish rearing in Akalura Lake (Table 20). Unlike the 1990 survey, in 1991, Area B (*See* Figure 3), located at the east arm of the lake, had the highest density and population of fish (1,707,631). Population estimates for Areas A and C (Transects 1, 2, 5, and 6) were 556,626 and 907,624, respectively. Individual transect population estimates ranged from 1,163,671 for Transect 3 to 268,567 for Transect 1 (Table 21). An examination of the horizontal distribution of fish for all transects combined revealed 71.4% of the targets were located along the north-south transects (1-4) and 28.6% were located along east-west transects (5-6) (Table 22). Data from the north-south transects indicated 43.0% of the fish were located in the middle section of the lake, with 30.8% and 26.2% found in the north and south sections, respectively. Data from the east-west transects revealed 35.1% of the fish were in the middle section, while 34.8% and 30.1% were in the east and west sections, respectively. The majority

Table 18. Horizontal distribution of the estimated population by lake section for the 29 September 1990 survey of Akalura Lake.

Section	Population (Number)	Distribution (Percent)
North	824,304	35.3
Middle	871,837	37.4
South	637,562	27.3
Total (n-s)	2,333,703	57.5
East	626,566	36.3
Middle	694,603	40.2
West	405,455	23.5
Total (e-w)	1,726,624	42.5
Total (all)	4,060,327	-

Table 19. Vertical distribution of fish density by depth strata for the 29 September 1990 survey of Akalura Lake.

Depth (m)	Density (#/1000 m^2)	Percent of Total
2 - 5	5,241.2	36.0
5 - 9.5	5,273.4	36.2
9.5 -14	2,245.3	15.4
14 - 18.5	1,598.9	11.0
18.5 - 23	202.7	1.4
23 - 27	0.0	0.0
Total	14,561.5	100.0

Table 20. Densities and population estimates of juvenile fish rearing in Akalura Lake by transect based on the 6 October 1991 hydroacoustic survey.

Transect	Mean fish density (no./1000 m^2)	Area (X 1000 m^2) transect	Area (X 1000 m^2) total	Weighted mean fish density (no./1000 m^2)	Variance	Fish population	Variance
1	455.03	593					
2	499.64	574	1,167	477.0	4.98E+02	556,626	6.8E+08
3	767.64	1,514					
4	564.63	966	2,480	688.6	9.80E+03	1,707,631	6.0E+10
5	802.92	754					
6	603.24	501	1,255	723.2	9.56E+03	907,624	1.5E+10
					Total	3,171,881	7.60E+10
				95% confidence interval (+/-)		540,383	

Table 21. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 06 October 1991 survey of Akalura Lake.

Transect (T)	Section	Depth Interval (m) 2-5	5-9.5	9.5-14	14-18.5	18.5-23	23-27.5	Total	Area (x10^3 m^2)	Pop. Est.
1	North	441.8	3.0	0.0	0.0	0.0	0.0	444.8	203	90,288
	Middle	328.5	58.0	0.0	0.0	0.0	0.0	386.5	203	78,460
	South	435.6	98.2	0.0	0.0	0.0	0.0	533.8	187	99,819
Total (T-1)		1,205.8	159.2	0.0	0.0	0.0	0.0	1,365.1	593	268,567
2	North	425.2	149.7	10.2	0.0	0.0	0.0	585.0	184	107,647
	Middle	225.5	198.3	108.9	15.6	0.0	0.0	548.2	195	106,895
	South	225.9	104.0	32.2	3.6	0.0	0.0	365.6	195	71,296
Total (T-2)		876.5	451.9	151.3	19.1	0.0	0.0	1,498.8	574	285,838
3	North	426.8	253.2	39.8	0.0	0.0	0.0	719.8	507	364,939
	Middle	557.6	238.5	139.4	62.4	11.0	0.0	1,008.9	507	511,492
	South	210.0	103.0	107.0	150.6	4.0	0.0	574.5	500	287,240
Total (T-3)		1,194.4	594.7	286.2	212.9	15.0	0.0	2,303.1	1,514	1,163,671

Table 21 continued. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 06 October 1991 survey of Akalura Lake.

Transect (T)	Section	Depth Interval (m) 2-5	5-9.5	9.5-14	14-18.5	18.5-23	23-27.5	Total	Area (x10^3 m^2)	Pop. Est.
4	North	184.1	187.9	34.5	3.8	0.0	0.0	410.3	326	133,748
	Middle	276.9	296.9	204.6	84.3	0.0	0.0	862.7	320	276,058
	South	55.8	124.5	141.7	98.8	0.0	0.0	420.9	320	134,682
Total (T-4)		516.7	609.3	380.9	186.9	0.0	0.0	1,693.8	966	544,487
5	East	378.1	325.7	56.2	0.0	0.0	0.0	760.0	256	194,552
	Middle	379.8	368.1	174.4	0.0	0.0	0.0	922.2	249	229,638
	West	480.9	231.7	14.0	0.0	0.0	0.0	726.5	249	180,908
Total (T-5)		1,238.7	925.5	244.6	0.0	0.0	0.0	2,408.8	754	605,099
6	East	451.5	279.5	7.2	0.0	0.0	0.0	738.1	164	121,055
	Middle	109.2	306.6	126.0	0.0	0.0	0.0	541.7	164	88,840
	West	394.9	124.9	10.1	0.0	0.0	0.0	529.9	173	91,664
Total (T-6)		955.5	710.9	143.3	0.0	0.0	0.0	1,809.7	501	301,559
Lake Total		5,987.8	3,451.5	1,206.1	418.9	15.0	0.0	11,079.3	4,902	3,169,221

Table 22. Horizontal distribution of estimated population by lake section for the 06 October 1991 survey of Akalura Lake.

Section	Population (Number)	Distribution (Percent)
North	696,622	30.8
Middle	972,904	43.0
South	593,036	26.2
Total (n-s)	2,262,563	71.4
East	315,607	34.8
Middle	318,478	35.1
West	272,573	30.1
Total (e-w)	906,658	28.6
Total (all)	3,169,221	-

Table 23. Vertical distribution of fish density by depth strata for the 06 October 1991 survey of Akalura Lake.

Depth (m)	Density (#/1000 m^2)	Percent of Total
2 - 5	5,987.8	54.0
5 - 9.5	3,451.5	31.2
9.5 -14	1,206.1	10.9
14 - 18.5	418.9	3.8
18.5 - 23	15.0	0.1
23 - 27	0.0	0.0
Total	11,079.3	100.0

of fish were distributed vertically in the uppermost intervals with highest densities found in the 2-5 m (54.0%) and 5-9.5 m (31.2%) depth ranges (*See* Table 23). The lowest densities were observed in the 18.5-23 meter range (0.1%).

Townetting in Akalura Lake on 11 May 1991 resulted in a catch of 54 sockeye juveniles (including 4 newly emergent fry) that represented 12.2% of the total catch (*See* Table 5). The remainder of the catch comprised 387 sticklebacks (*See* Table 11). The sockeye CPUE was 0.75. Of the total sockeye catch, 6.8% were age-0 juveniles, 54.5 % age-1 juveniles, and 38.6% age-2 juveniles (*See* Table 12). The mean weight, length, and condition coefficient of age-0 sockeye fry was 0.2 g, 29 mm, and 0.79 K_D, respectively. The mean weight, length, and condition coefficient of age-1 sockeye fingerlings was 1.0 g, 50 mm, and 0.78 K_D, respectively. The mean weight, length, and condition coefficient of age-2 sockeye fingerlings was 2.4 g, 68 mm, and 0.74 K_D, respectively. (Weight, length, and condition information was based on fish preserved for over a year in alcohol.)

Townetting in Akalura Lake on 05 October 1991 resulted in a catch of 147 sockeye salmon juveniles that represented 1.4% of the total catch (*See* Table 5). The remainder of the catch comprised 10,765 sticklebacks and 3 Dolly Varden char (*See* Table 13). The sockeye CPUE was 2.10. The sockeye population estimate determined from hydroacoustics and townetting was 44,380 $\pm$ 20,846. Of the total sockeye catch, 36.7% were age-0 and 63.3% age-1 juveniles (*See* Table 12). The mean weight, length, and condition coefficient of age-0 fish was 1.4 g, 52 mm, and 0.95 K_D, respectively. The mean weight, length, and condition coefficient of age-1 fish was 3.8 g, 74 mm, and 0.93 K_D, respectively.

Upper Station Lake

The 28 September 1990 hydroacoustic survey revealed a population estimate of 3,843,823 $\pm$ 467,506 juvenile fish (Table 24). Area A, represented by Transects 1 and 2 located at the east arm of

Table 24. Densities and population estimates of juvenile fish rearing in Upper Station Lake by transect based on the 28 September 1990 hydroacoustic survey.

Transect	Mean fish density (no./1000 m^2)	Area (X 1000 m^2) transect	Area (X 1000 m^2) total	Weighted mean fish density (no./1000 m^2)	Variance	Fish population	Variance
1	856.89	819					
2	975.96	973	1,792	921.5	3.52E+03	1,651,396	1.1E+10
3	505.05	1,005					
4	454.14	911	1,916	480.8	6.46E+02	921,303	2.4E+09
5	457.66	770					
6	402.04	942	1,712	427.1	7.66E+02	731,122	2.2E+09
7	448.58	817					
8	205.09	846	1,663	324.7	1.48E+04	540,002	4.1E+10
					Total	3,843,823	5.7E+10
				95% confidence interval (+/-)		467,506	

the lake, had the highest density and population of fish (1,651,396), while population estimates for Area D (Transects 7 and 8) had the lowest with a population estimate of 540,002 (Figure 4). Fish populations of Areas B and C (Transects 3-6) were estimated at 921,303 and 731,122, respectively. Individual transect population estimates ranged from 946,339 for Transect 2 to 175,864 for Transect 8 (Table 25). The horizontal distribution of fish for all transects combined revealed 37.9% of the targets were located along the southeast section of the lake, while 33.8% and 28.4% of targets were located in the middle and northwest sections, respectively (Table 26). Fish were distributed vertically with highest densities found in the uppermost three depth intervals and primarily in the 9-18 m range (46.8%) (Table 27). The lowest densities were observed below 27 m.

A total of 174 sockeye salmon juveniles were caught by townetting in Upper Station Lake on 28 September 1990. These amounted to 30.5% of the total catch (*See* Table 5). The remainder of the catch comprised of 397 sticklebacks (*See* Table 6). The sockeye CPUE was 1.91, and the juvenile sockeye population was estimated at 1,171,200 $\pm$ 142,723.

The 05 October 1991 hydroacoustic survey in Upper Station Lake resulted in a population estimate of 3,987,459 $\pm$ 555,705 juvenile fish (Table 28). Area B had the highest density and population of fish (1,222,742), while population estimates for Area A had the lowest estimate of 722,767 (Figure 4). Areas C and D were similar to Area B with estimates of 1,116,917 and 1,025,033, respectively. Individual transect population estimates ranged from 675,108 for Transect 7 to 282,220 for Transect 1 (Table 29). The horizontal distribution of fish for all transects combined revealed 40.3% of the targets were located along the middle section of the lake, while 39.3% and 20.4% of targets were located in the northwest and southeast sections, respectively

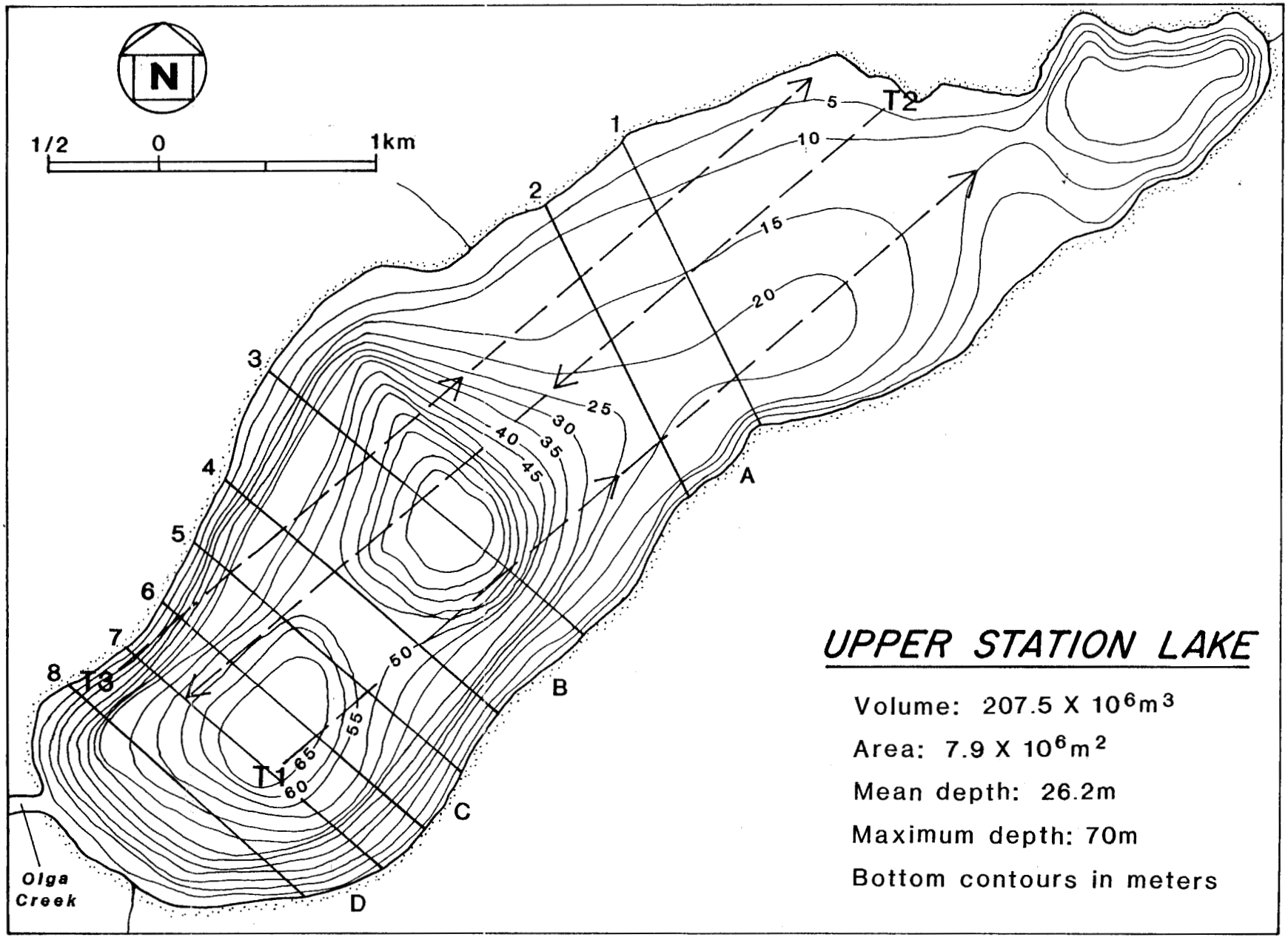

Figure 4. Morphometric map of Upper Station Lake showing hydroacoustic areas (A-D), transects (1-8), and townetting locations (T1-T3).

Table 25. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 28 September 1990 survey of Upper Station Lake.

		Depth Interval (m)									
Transect (T)	Section	2-9	9-18	18-27	27-36	36-45	45-54	54-69	Total	Area (x10^3 m^2)	Pop. Est.
1	Northwest	95.1	497.3	304.5	41.4	7.0	2.6	0.9	948.8	275	260,915
	Middle	150.9	662.1	207.6	25.3	2.6	2.6	1.7	1,052.8	275	289,523
	Southeast	277.8	203.1	73.9	9.6	1.6	2.4	0.8	569.2	269	153,115
Total (T-1)		523.8	1,362.4	586.0	76.3	11.3	7.7	3.4	2,570.8	819	703,552
2	Northwest	174.8	484.7	276.1	50.2	9.5	3.5	0.9	999.6	313	312,884
	Middle	115.7	605.7	203.4	28.0	7.0	4.4	0.9	965.1	330	318,470
	Southeast	401.4	464.2	81.6	4.1	2.5	0.8	0.0	954.5	330	314,985
Total (T-2)		691.9	1,554.6	561.0	82.3	19.0	8.7	1.8	2,919.2	973	946,339
3	Northwest	21.4	167.7	218.6	17.8	8.0	2.7	0.9	437.1	336	146,859
	Middle	109.8	158.7	97.9	7.6	3.4	1.7	1.7	380.8	336	127,935
	Southeast	293.2	333.2	68.6	1.6	2.4	0.0	0.8	699.8	333	233,027
Total (T-3)		424.3	659.6	385.1	27.1	13.8	4.4	3.4	1,517.6	1,005	507,821

Table 25 continued. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 28 September 1990 survey of Upper Station Lake.

		Depth Interval (m)									
Transect (T)	Section	2-9	9-18	18-27	27-36	36-45	45-54	54-69	Total	Area	Pop. Est.
4	Northwest	53.1	179.3	87.0	5.2	2.6	1.7	0.9	329.8	339	111,806
	Middle	62.0	181.7	159.9	15.7	6.1	4.4	1.7	431.6	279	120,419
	Southeast	202.3	253.0	134.0	6.7	3.3	1.7	0.0	601.0	293	176,081
Total (T-4)		317.4	614.0	380.9	27.6	12.1	7.8	2.6	1,362.4	911	408,306
5	Northwest	23.0	101.9	137.3	13.3	7.1	4.4	0.9	287.9	266	76,589
	Middle	36.5	176.1	281.0	18.7	7.1	7.1	2.7	529.1	266	140,735
	Southeast	174.2	263.8	104.7	11.7	1.7	1.7	0.8	558.5	238	132,930
Total (T-5)		233.7	541.7	523.0	43.7	15.9	13.2	4.4	1,375.5	770	350,255
6	Northwest	0.0	54.1	112.7	7.2	2.7	1.8	0.9	179.3	320	57,386
	Middle	42.4	123.7	254.4	15.9	4.4	2.7	0.9	444.3	311	138,184
	Southeast	163.8	272.6	130.8	7.6	3.4	2.5	0.8	581.6	311	180,862
Total (T-6)		206.2	450.4	497.9	30.7	10.5	7.0	2.6	1,205	942	376,431

Table 25 continued. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 28 September 1990 survey of Upper Station Lake.

		Depth Interval (m)									
Transect (T)	Section	2-9	9-18	18-27	27-36	36-45	45-54	54-69	Total	Area	Pop. Est.
7	Northwest	6.3	89.6	125.5	8.1	3.6	0.9	0.9	234.8	275	64,573
	Middle	31.9	109.8	233.7	25.7	7.1	1.8	0.9	410.7	275	112,929
	Southeast	109.6	361.9	209.6	12.2	3.5	2.6	0.8	700.2	267	186,943
Total (T-7)		147.7	561.2	568.8	45.9	14.1	5.3	2.6	1,346	817	364,444
8	Northwest	9.8	76.5	113.9	3.6	2.7	1.8	0.9	209.2	269	56,264
	Middle	21.1	102.9	51.9	6.2	1.8	2.6	0.9	187.3	247	46,251
	Southeast	58.5	117.9	31.4	7.6	5.1	0.8	0.8	222.3	330	73,349
Total (T-8)		89.4	297.4	197.2	17.3	9.5	5.3	2.6	619	846	175,864
Total All Transects		2,634.3	6,041.3	3,699.9	350.8	106.1	59.1	23.4	12,915.0	7,083.0	3,833

Table 26. Horizontal distribution of estimated population by lake section for the 28 September 1990 survey of Upper Station Lake.

Section	Population (Number)	Distribution (Percent)
Northwest	1,087,275	28.4
Middle	1,294,445	33.8
Southeast	1,451,292	37.9
Total	3,833,012	100.0

Table 27. Vertical distribution of fish density by depth strata for the 28 September 1990 survey of Upper Station Lake.

Depth (m)	Density (#/1000 m^2)	Percent of Total
2 - 9	2,634.3	20.4
9 - 18	6,041.3	46.8
18 - 27	3,699.9	28.6
27 - 36	350.8	2.7
36 - 45	106.1	0.8
45 - 54	59.1	0.5
54 - 69	23.4	0.2
Total	12,915.0	100.0

Table 28. Densities and population estimates of juvenile fish rearing in Upper Station Lake by transect based on the 5 October 1991 hydroacoustic survey.

Transect	Mean fish density (no./1000 m^2)	Area (X 1000 m^2) transect	Area (X 1000 m^2) total	Weighted mean fish density (no./1000 m^2)	Variance	Fish population	Variance
1	385.53	732					
2	450.47	978	1,710	422.7	1.03E+03	722,767	3.0E+09
3	530.57	948					
4	679.57	912	1,860	603.6	5.55E+03	1,122,742	1.9E+10
5	753.27	873					
6	497.63	923	1,796	621.9	1.63E+04	1,116,917	5.3E+10
7	628.80	1073					
8	539.80	649	1,722	595.3	1.86E+03	1,025,033	5.5E+09
					Total	3,987,459	8.0E+10
				95% confidence interval (+/-)		555,705	

Table 29. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 05 October 1991 survey of Upper Station Lake.

Transect (T)	Section	Depth Interval (m) 2-5	5-9	9-18	18-27	27-36	36-45	45-54	54-69	Total	Area (x10^3 m^2)	Pop. Est.
1	Northwest	6.9	45.8	98.6	26.9	7.1	1.7	0.5	0.0	187.4	244	45,721
	Middle	10.6	42.5	107.4	47.7	3.4	2.8	3.0	0.1	217.4	244	53,043
	Southeast	42.0	126.1	143.7	209.9	78.6	96.2	54.3	1.1	751.9	244	183,456
Total (T-1)		59.5	214.4	349.7	284.5	89.0	100.7	57.7	1.2	1,156.6	732	282,220
2	Northwest	44.5	128.2	191.5	55.3	14.8	3.6	2.5	3.1	443.6	326	144,607
	Middle	108.0	239.0	195.9	87.6	25.9	8.7	4.3	6.4	675.8	326	220,314
	Southeast	31.6	44.2	57.5	77.6	11.4	5.5	2.1	2.2	232.0	326	75,625
Total (T-2)		184.1	411.4	444.9	220.5	52.0	17.8	8.9	11.7	1,351.4	978	440,547
3	Northwest	116.1	196.8	167.3	65.4	37.0	31.0	3.2	3.9	620.7	316	196,144
	Middle	157.9	206.3	234.7	126.6	46.0	16.3	5.5	6.6	799.9	316	252,781
	Southeast	31.0	31.4	45.2	40.8	12.4	6.3	1.9	2.1	171.0	316	54,049
Total (T-3)		305.0	434.6	447.2	232.7	95.4	53.6	10.6	12.6	1,591.7	948	502,974

Table 29 continued. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 05 October 1991 survey of Upper Station Lake.

Transect (T)	Section	Depth Interval (m) 2-5	5-9	9-18	18-27	27-36	36-45	45-54	54-69	Total	Area (x10^3 m^2)	Pop. Est.
4	Northwest	137.1	320.2	210.6	104.3	27.9	5.9	3.3	2.1	811.3	304	246,644
	Middle	108.0	242.3	205.7	107.6	36.1	10.4	5.7	7.7	723.5	304	219,950
	Southeast	139.7	199.0	105.9	29.3	21.3	4.3	2.1	2.3	503.8	304	153,155
Total (T-4)		384.7	761.4	522.2	241.2	85.4	20.7	11.1	12.0	2,038.7	912	619,750
5	Northwest	184.4	259.5	247.5	154.3	48.8	24.5	3.4	4.3	926.7	291	269,673
	Middle	151.2	246.8	223.9	120.8	57.2	15.6	11.2	10.4	837.2	291	243,616
	Southeast	120.0	128.2	149.9	65.3	22.3	4.6	2.3	3.3	495.9	291	144,301
Total (T-5)		455.6	634.5	621.4	340.3	128.3	44.8	17.0	18.0	2,259.8	873	657,590
6	Northwest	51.1	204.7	222.9	142.9	65.8	24.7	7.9	4.6	724.6	307	222,449
	Middle	114.8	165.4	184.2	88.3	29.4	15.8	10.7	7.2	615.7	308	189,648
	Southeast	27.0	69.9	29.3	9.0	7.0	5.1	2.5	2.7	152.6	308	46,998
Total (T-6)		192.9	440.0	436.4	240.2	102.2	45.6	21.1	14.5	1,492.9	923	459,095

Table 29 continued. Fish density (#/1000 m^2) by depth strata for transect thirds including survey areas, and population estimates for the 05 October 1991 survey of Upper Station Lake.

Transect (T)	Section	Depth Interval (m) 2-5	5-9	9-18	18-27	27-36	36-45	45-54	54-69	Total	Area (x10^3 m^2)	Pop. Est.
7	Northwest	85.7	234.1	215.1	166.1	116.5	15.9	4.8	2.6	840.8	358	301,003
	Middle	114.5	327.9	224.6	79.4	40.3	14.5	6.2	8.1	815.5	358	291,938
	Southeast	68.6	91.0	40.9	16.9	4.4	3.4	2.0	3.0	230.2	357	82,167
Total (T-7)		268.9	653.0	480.6	262.4	161.1	33.8	12.9	13.7	1,886.4	1,073	675,108
8	Northwest	61.7	179.3	230.9	134.7	51.7	0.0	0.0	0.0	658.2	215	141,502
	Middle	56.0	172.0	281.0	69.0	48.4	1.9	0.0	0.0	628.3	217	136,348
	Southeast	19.7	35.8	72.4	167.0	34.8	3.4	0.0	0.0	332.9	217	72,246
Total (T-8)		137.4	387.1	584.2	370.7	134.9	5.3	0.0	0.0	1,619.4	649	350,096
Total All Transects		1,988.1	3,936.4	3,886.6	2,192.4	848.3	322.1	139.4	83.6	13,396.9	7,088	3,987,379

(Table 30). The vertical distribution of fish revealed the highest densities in the 5-9 m (29.4%), and 9-18 m (29.0%) depth ranges (Table 31). The lowest densities were observed in the 45-54 m (1.0%) and 54-69 m depth ranges (0.6%).

Townetting on 08 May 1991 in Upper Station Lake resulted in a catch of 14 sockeye salmon juveniles (including 5 newly emergent fry) representing 1.0% of the total catch (*See* Table 5). The remainder of the catch comprised 1,353 threespine sticklebacks (*See* Table 11). The sockeye CPUE was 0.16. Of the total sockeye catch, 30.8% were age-0 juveniles, 15.4% age-1 juveniles, and 53.8% age-2 juveniles (*See* Table 12). The mean weight, length, and condition coefficient of age-0 fish was 0.3 g, 31 mm, and 0.87 K_D, respectively. The mean weight, length, and condition coefficient of age-1 fish was 3.3 g, 73 mm, and 0.87 K_D, respectively. The mean weight, length, and condition coefficient of age-2 fish was 10.4 g, 109 mm, and 0.79 K_D, respectively.

Townetting on 04 October 1991 in Upper Station Lake resulted in a catch of 160 sockeye juveniles that comprised 9.8% of the total catch (*See* Table 5). The remainder of the catch comprised 1,480 sticklebacks (*See* Table 13). The sockeye CPUE was 1.70 and the juvenile sockeye population was estimated at 391,020 $\pm$ 54,328. Of the total sockeye catch, 72.5% were age-0 and 27.5% age-1 juveniles (*See* Table 12). The mean weight, length, and condition coefficient of age-0 fish was 1.7 g, 56 mm, and 0.85 K_D, respectively. The mean weight, length, and condition coefficient of age-1 fish was 7.0 g, 91 mm, and 0.91 K_D, respectively.

Townetting on 21 September 1992 in Upper Station Lakes resulted in a catch of 275 sockeye juveniles that comprised 33.6% of the total catch (*See* Table 5). The remainder of the catch comprised 543 sticklebacks. The sockeye CPUE was 2.96. Of the total sockeye catch, 77.5% were age-0 and 22.5% age-1 juveniles (*See* Table 15). The mean weight, length, and condition coefficient of age-0 juveniles was 2.9 g, 67 mm, and 0.89 K_D, respectively. The

Table 30. Horizontal distribution of estimated population by lake section for the 05 October 1991 survey of Upper Station Lake.

Section	Population (Number)	Distribution (Percent)
Northwest	1,567,743	39.3
Middle	1,607,639	40.3
Southeast	811,997	20.4
Total	3,987,379	100.0

Table 31. Vertical distribution of fish density by depth strata for the 05 October 1991 survey of Upper Station Lake.

Depth (m)	Density (#/1000 m^2)	Percent of Total
2 - 5	1,988.1	14.8
5 - 9	3,936.4	29.4
9 - 18	3,886.6	29.0
18 - 27	2,192.4	16.4
27 - 36	848.3	6.3
36 - 45	322.1	2.4
45 - 54	139.4	1.0
54 - 69	83.6	0.6
Total	13,396.9	100.0

mean weight, length, and condition coefficient of age-1 juveniles was 8.4 g, 90 mm, and 1.03 K_D, respectively.

DISCUSSION

Red Lake

The population estimates of juvenile sockeye salmon in Red Lake in the falls of 1990 and 1991, based on the hydroacoustic survey and townetting, were 101,000 and 632,000, respectively (*See* Table 5). This compares to the total fish population, during the same periods, of 7.2 million and 9.4 million, respectively (*See* Tables 1 and 7). Since the townet catches (CPUE = 0.22-0.67) revealed a very low proportion (<2%) of sockeye, the fall population estimates of juvenile sockeye do not correspond with resulting smolt population estimates; that is, the 1991 and 1992 sockeye smolt estimates were 263,500 and 1,420,000, respectively (Barrett et al. 1992).

The probable reasons for these discrepancies may include: (1) the fall fry may have been unavailable (near-boundary distribution) to the hydroacoustic gear, (2) differential net avoidance may have biased species composition, (3) errors in the technique to estimate the smolt migration, or (4) a combination of the above factors (Gary Kyle[2], personal communication). In both the 1990 and 1991 hydroacoustic surveys, the distribution of fish in undetectable areas of the lake (near-surface, -bottom, or -shore) was not evident (*See* Tables 3, 4, 9, and 10). The smolt subsampling (trapping) technique in Red Lake was compared with a total enumeration weir count in 1992, and the absolute error was found to be less than 10% (Barrett et al. 1992). One of the most likely sources of error in hydroacoustical estimations of fish in lakes is the bias associated with sampling for species and cohort

[2] Alaska Department of Fish and Game, Limnology Laboratory, 34828 Kalifornsky Beach Road, Suite B, Soldotna, Alaska 99669.

composition (Kyle 1990). Differential avoidance of the townet by species and cohorts and changes in netting efficiency related to differing moonlight and cloud cover (Robinson and Barraclough 1978) influences the composition of catch. There is the potential, therefore, for biasing estimates of hydroacoustically derived fish populations when townet catch information is used to partition total fish population estimates by species and age.

Unfortunately, the loss of samples due to inadequate preservation techniques in 1990 precludes a complete analysis of size by comparing all age classes by brood year; however, a partial comparison can be made. In 1989, the year of high adult escapement and spawning, the resulting age-1 sockeye fry rearing in the lake in May 1991 averaged 69 mm in length and 2.4 g in weight (*See* Table 12). By October 1991, these fry averaged 81 mm and 4.4 g. These sizes reflect preservation in alcohol with approximately 20% shrinkage. A correction for this shrinkage results in a fry size of 86 mm and 3.0 g in May, and 101 mm and 5.5 g in October. The age-1 fall fry sampled before preservation in 1992 (BY 1990) averaged 92 mm and 7.4 g (24 September), and 102 mm and 9.0 g (23 September), or a 35%-64% increase in weight (*See* Table 15). These data suggest that the age-1 fry of BY 1989 reared under conditions that limited growth, whereas the age-1 fry from the subsequent brood year reared under more favorable conditions. This suggests the presence of interspecific competition among fry rearing from BY 1989.

Akalura Lake

Fall population estimates of juvenile sockeye salmon in 1990 and 1991 were similar to those observed at Red Lake—low compared to the subsequent spring smolt estimates. In the fall of 1990, based on the hydroacoustic and townet survey, 209,350 juvenile sockeye were estimated to be in the lake (*See* Table 5). In the spring of 1991, however, Barrett et al. (1992) estimated that 310,000 smolts migrated. Similarly, in the fall of 1991, an estimated 44,380 juvenile sockeye were in the lake compared to

the 1992 smolt estimate of 193,200 (Barrett et al. 1992). Unlike Red Lake, however, Akalura Lake had a high percentage of fish near the surface in both surveys (*See* Tables 18, 19, 22, and 23), but exhibited a more uniform distribution of fish in the pelagic area of the lake (*See* Tables 18 and 22). It appears that, in addition to the biases of species and cohort composition associated with townetting, the additional factor of near surface distribution may have caused an underestimate of the number of fall fry.

The age-1 fall fry sampled in October of 1991 were produced from a large escapement in 1989. The preserved average size of these fry was 74 mm and 3.8 g and had a condition coefficient of 0.93 (*See* Table 12). After correction for shrinkage due to preservation in alcohol, the average fry size is 93 mm and 4.8 g. Fall fry size information is not available for other brood years with lower escapements. However, the weights of age-1 smolts for BY 1988 through BY 1990 appeared similar (Barrett et al. 1992). It appears, therefore, that the high escapement into Akalura Lake had no apparent effect on juvenile sockeye smolt size.

Upper Station Lakes

The fall population estimates of juvenile sockeye salmon in Upper Station Lake in 1990 and 1991 were substantially different, with 1,171,200 and 391,000 estimated, respectively (*See* Table 5). These estimates were also lower than the smolt estimates of 2,445,000 in 1991 and 2,395,000 in 1992 (Barrett et al. 1992). Although near surface fish distribution most likely resulted in some missing targets as indicated by the vertical distribution (*See* Tables 27 and 31), the horizontal distribution was fairly uniform among the three sections of the lake (*See* Tables 26 and 30). It is most likely, therefore, that the underestimation of fall fry is a result of the bias of species composition determination from townetting.

Upper Station Lake, considered the "control" lake, did not receive excessive escapement in 1989. The age-1 fry sampled in the fall of 1991 had a preserved size of 91 mm and 7.0 g (114 mm and 8.8 g after correction for shrinkage), and a condition coefficient of 0.91 (*See* Table 12). The size of age-1 and age-2 smolts did not exhibit large changes for BY 1988 through BY 1990 (Barrett et al. 1992).

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